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DANISH HOUSEHOLD LOAD PROFILES AND THE EFFECT OF SAVINGS FOR APPLIANCE CATEGORIES

Bergen BEEER 2015 Conference, NHH

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Systems Analysis Division

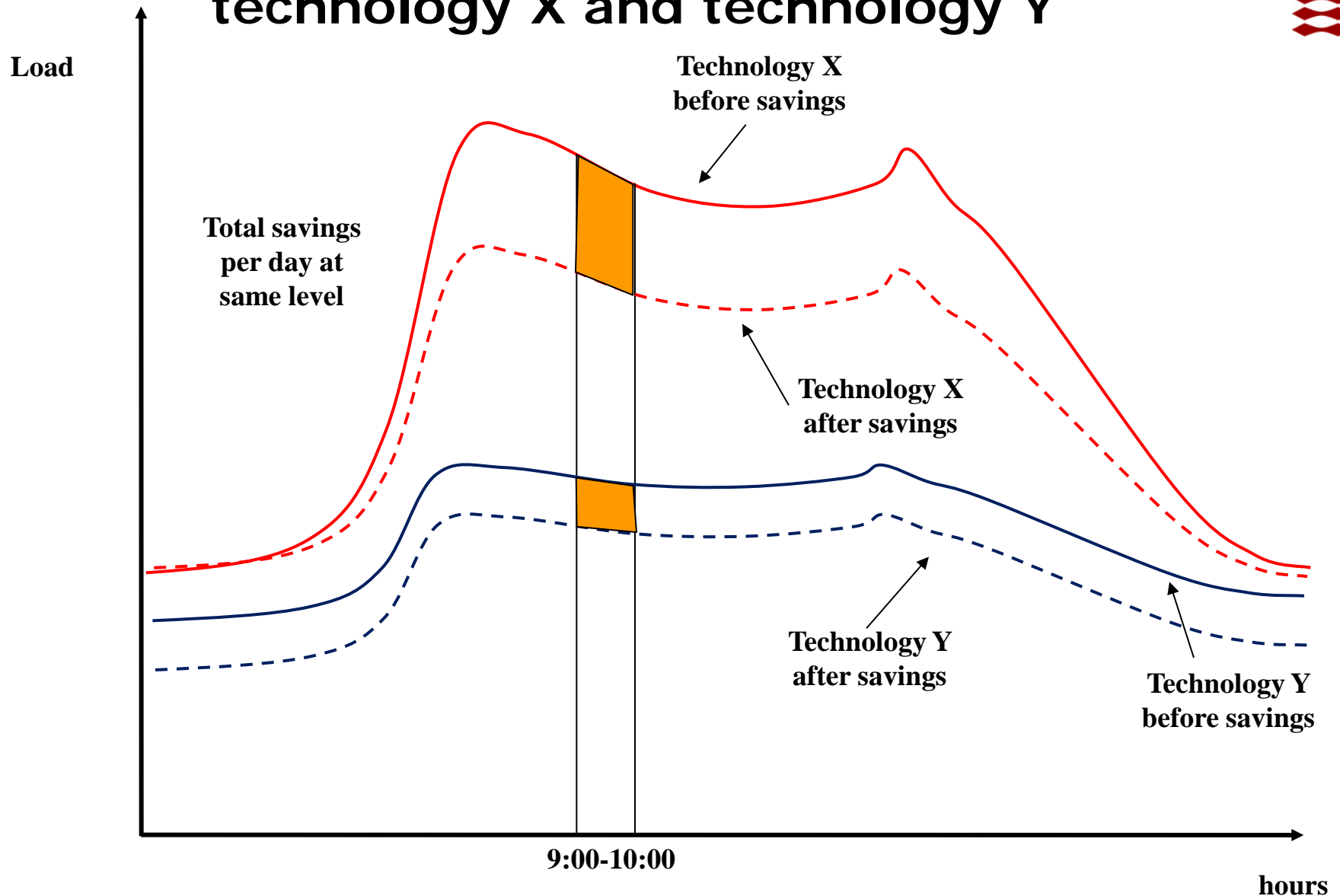
DTU Management Engineering

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The emission effects and capacity value of electricity savings

- Hypothesis: the savings of fossil fuel and power capacity varies substantially across the categories of appliances when end-use efficiency is increased
- Electricity savings for X and Y technology is assumed identical per day/year
- Electricity content of fossil fuel savings at peak hours much higher than for off-peak hours
- Savings for both technologies in terms of fuel cost - but dependent on supply situation - privately depending on tariff regime (fixed or day-ahead based tariff)
- Capacity value of electricity savings for peak hours adds to system cost savings but not private savings
- From both perspectives savings of technology X should be preferred to technology Y

Load profile (electricity) and savings for technology X and technology Y

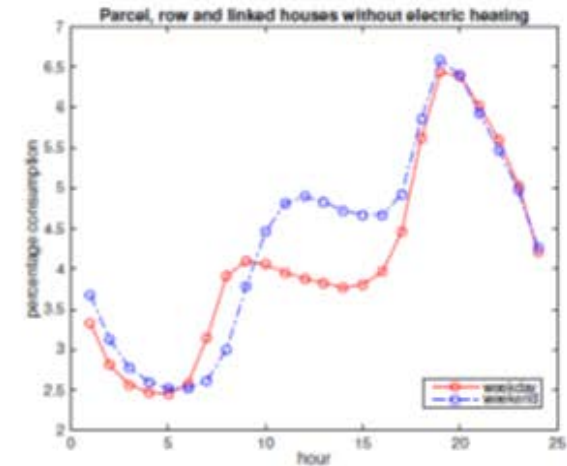
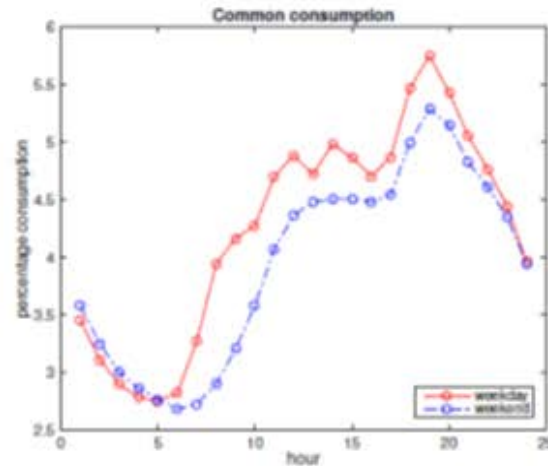
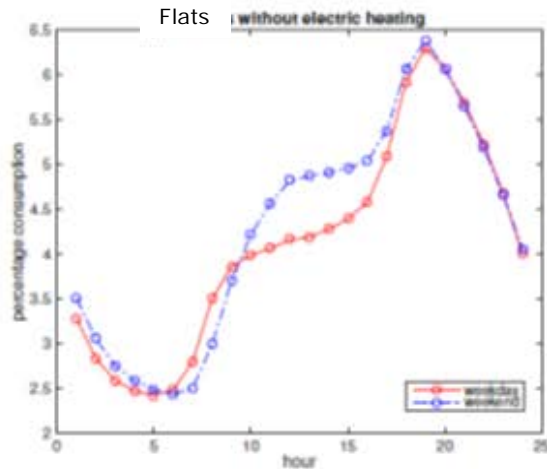


Using small data sample for household appliances load profiles and calibrating to annual consumption for a comparable category of appliance

We use a combination of three/four datasets:

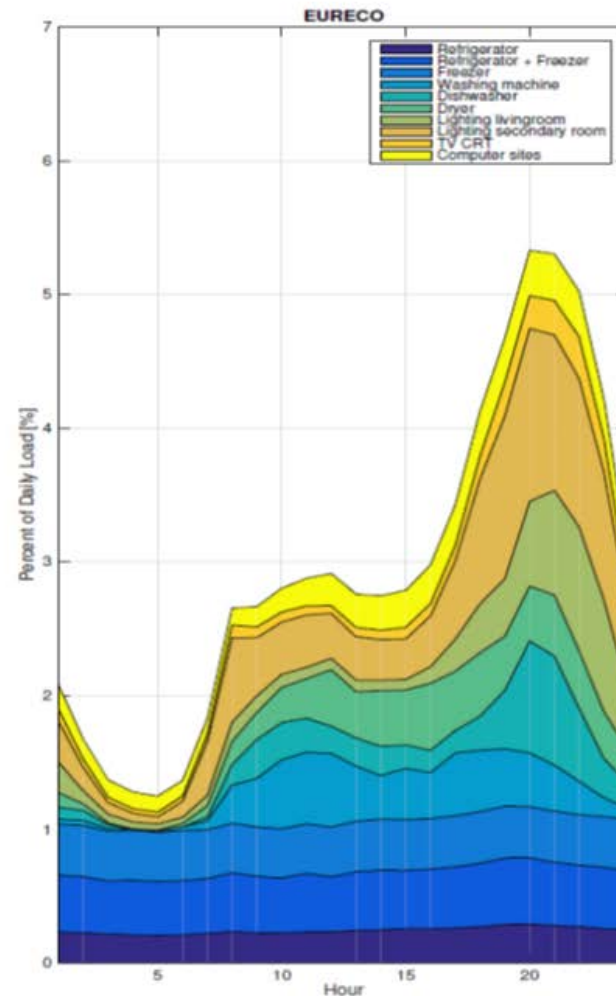
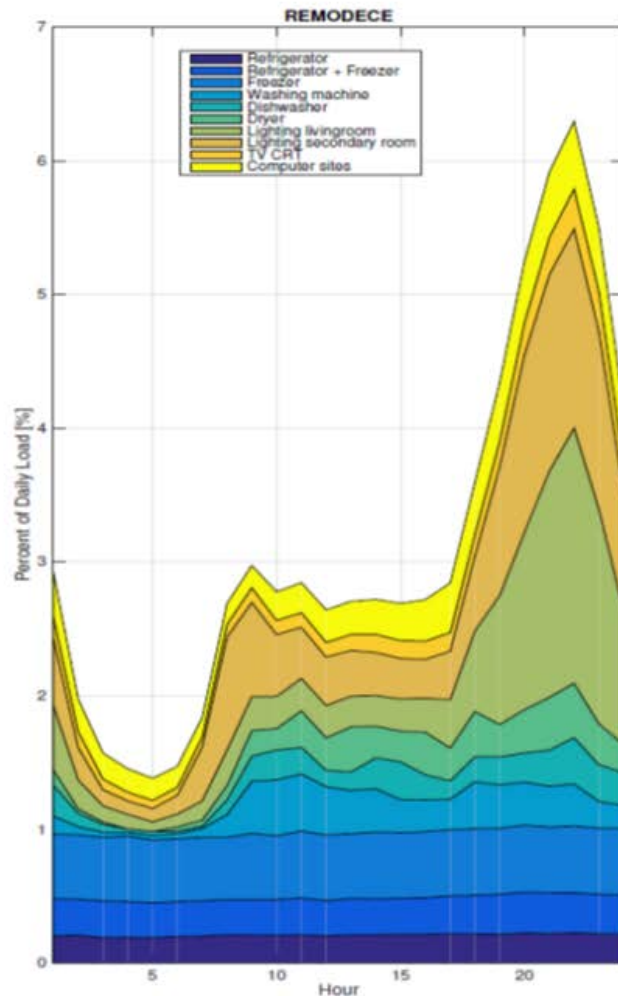
- 1) Measured Danish daily load profile by hour for the aggregate household demand in 2008, 5 building categories
- 2) Danish composition of stocks of appliances on categories and their annual electricity consumption (Danish Energy Agency)
- 3) EURECO project data for appliance category load profiles, 2002 data for 50 DK households (Odense area)
- 4) REMODECE project data for appliance category load profiles (approx 2008 for 100 DK households, weekday + weekend) European profile scaled to average DK consumption level and ownership ratio

Aggregate household load profiles



- Hourly load for weekday and weekend both divided by total daily consumption - level difference not illustrated - three categories of consumption
- Load profile for households similar for weekdays and weekends except for a delay in consumption in the first half of weekend-days
- Households contribute to load variation leading to higher average fossil fuel consumption
- Households also contribute to capacity peaks
- Hereby savings in household consumption can potentially contribute to reduce both fossil fuel consumption and capacity costs

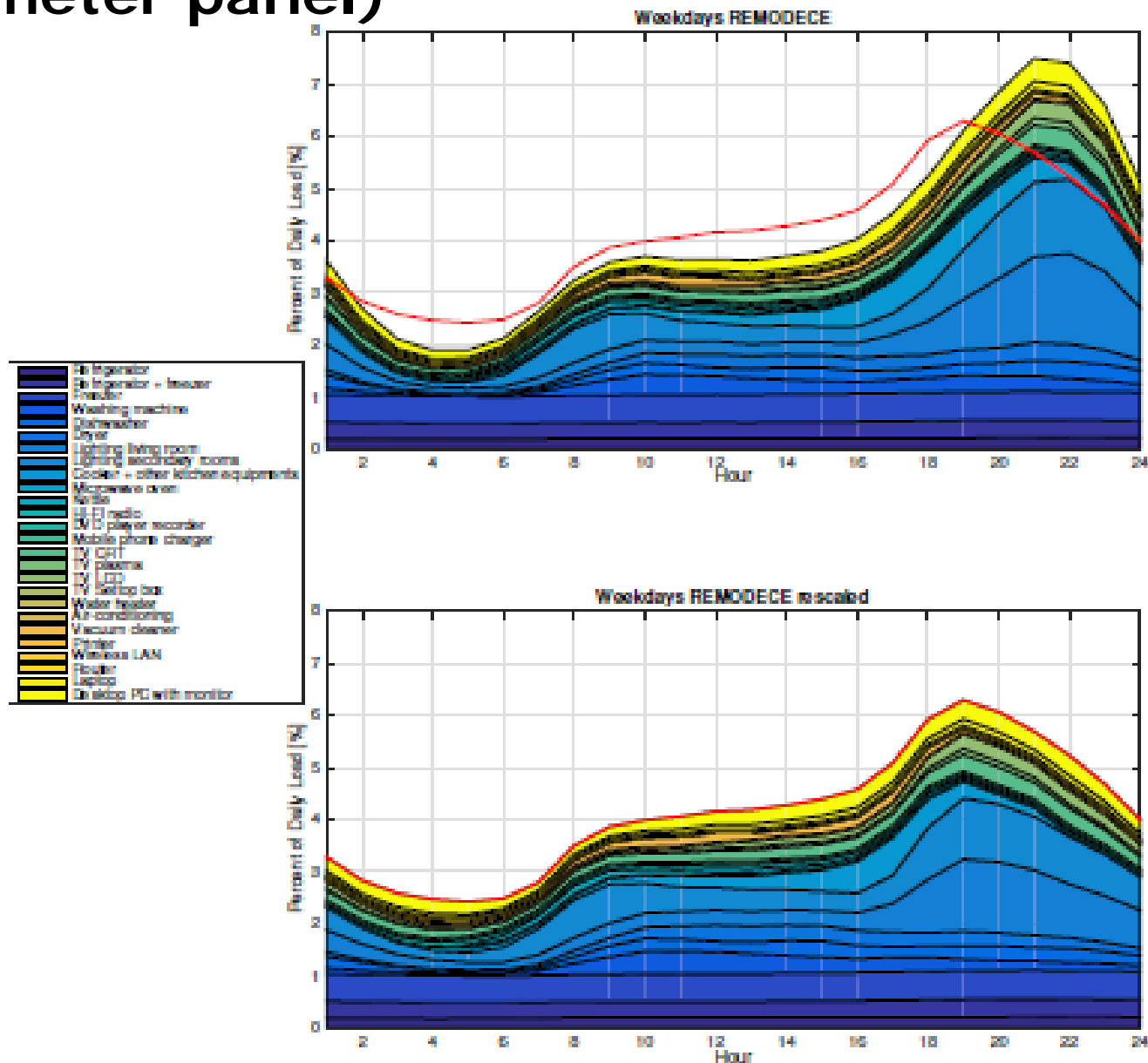
Composition of load profiles for household electricity demand in Denmark on appliances, comparing two datasets



Load profile varies substantially between categories

- We compared the profiles of the two different datasets (REMODECE, EURECO) and find some differences for the total peak level and position, but the pattern for individual appliances are quite similar
- The blue categories in the bottom varies very little across the hours
- These three cold appliances are practically stable and the benefits of energy savings will be less than for some of the other appliances
- Lighting has a much more interesting profile for achieving benefits of saving in terms of the average savings in hours of high demand
- - lighting has the peak slightly after the daily peak, but the level is pretty high also around the peak
- However this is the average profile for a year and does not show the seasonal differences
- We use an additional data set to determine the difference in load profile for each season

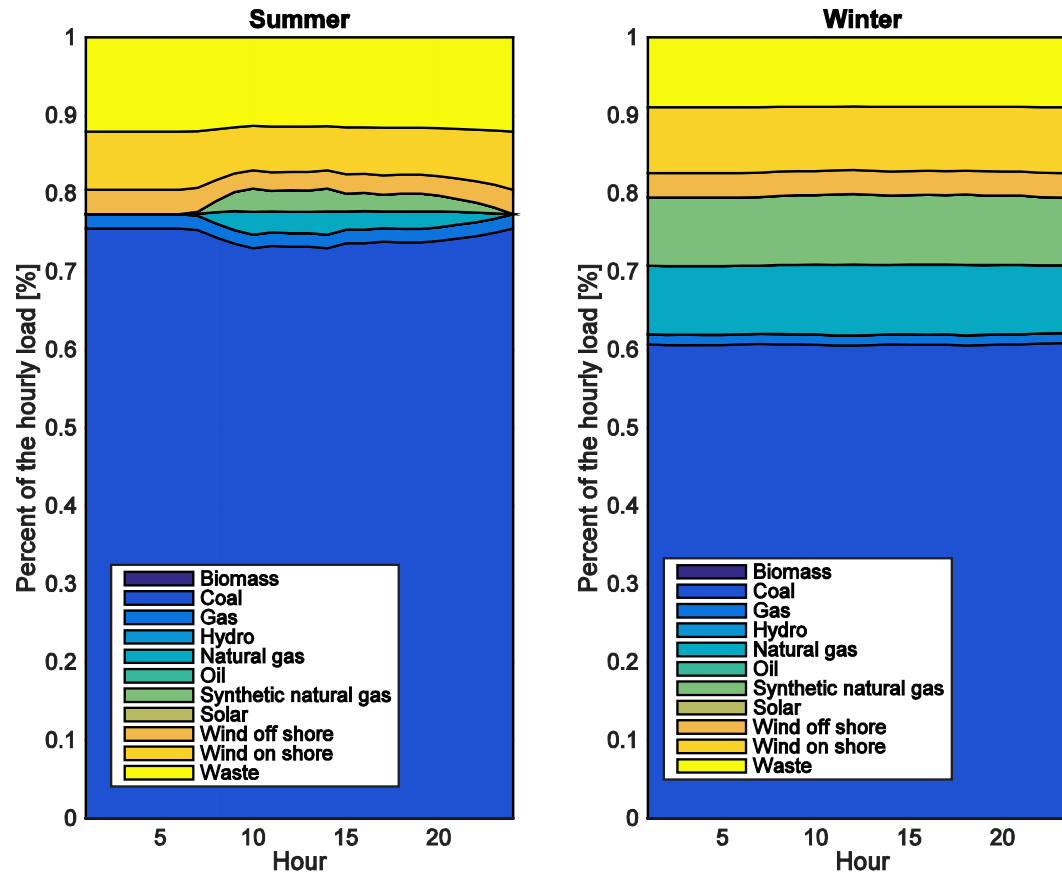
Rescaling the REMODECE European profile data to the 2008 average household hourly load profile (meter panel)



Example of simplified static calculation for emissions

- Electricity efficiency increase for lighting and cold appliances assumed identical (20% efficiency increase)
- No behavioural change following the energy service cost reduction (at least reasonable to assume that the profile does not change)
- Consumption profile for category varies substantially during the day and seasonally
- Volume of annual category consumption is different (lighting x % and cold appliances y%)
- Combining with static power sector fuel consumption for corresponding hours and season
- Will be refined using extended power sector model details and possible dynamic effects - WP5

Average hourly fuel shares in DK power generation for summer and winter season (TIMES-DK output 2011)



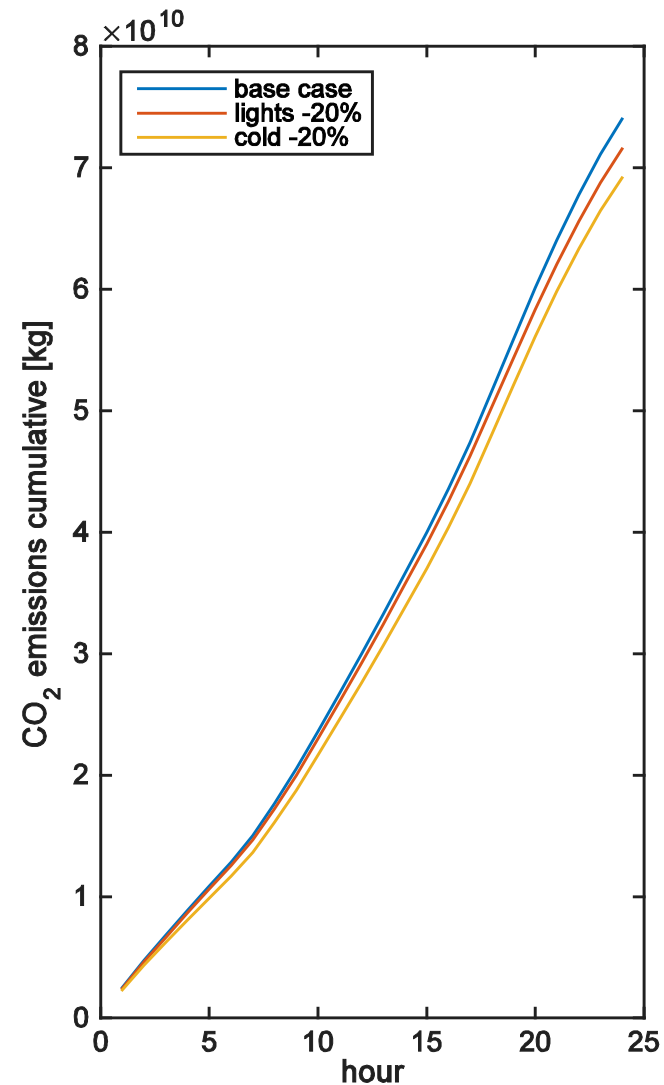
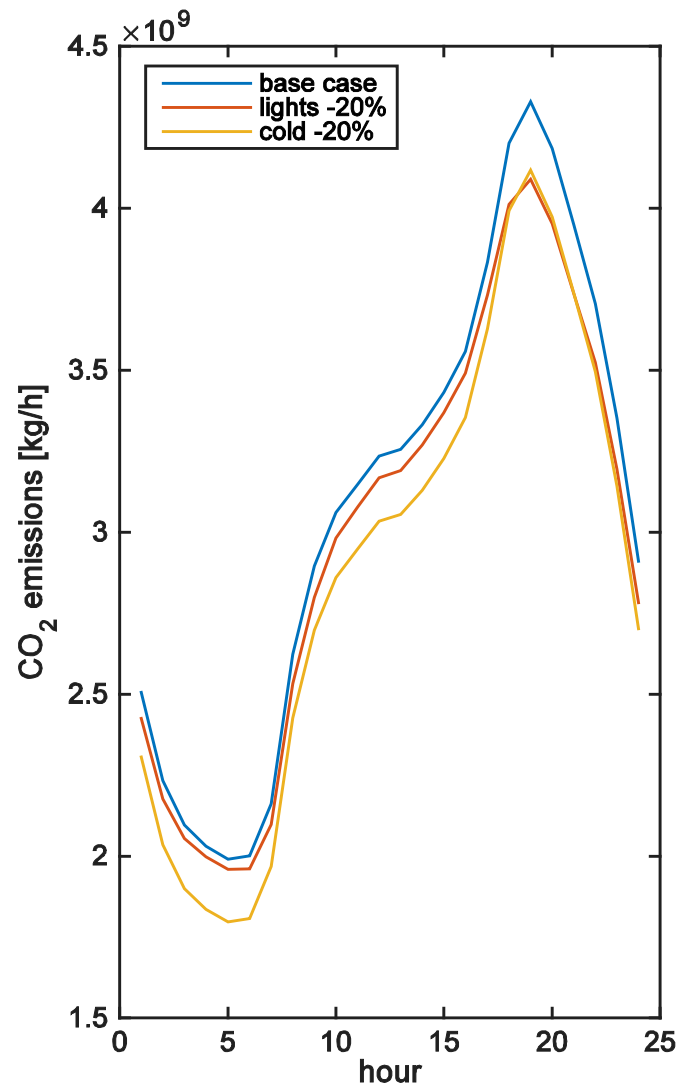
- Fuel shares vary the most across hours during summer
- Waste with higher proportion during summer
- Coal with higher proportion during summer
- Wind approx same share in summer and winter
- Natural gas and oil only squeeze in during peak hours in the summer, but has a steady and higher share during winter
- Natural gas divided in a couple of technologies (has to be checked)
- This suggest that summer consumption would on average have a higher CO₂ content due to the coal, instead of natural gas and oil
- Marginal fuels and emissions thus vary the most in summer

Calculation alternative with constant emissions per hour

- Alternative A
- Emission per hour is constant within each season (summer, winter)
- 20% efficiency increase for annual consumption of each appliance category
- This alternative quantifies the effect of different seasonal distribution of appliance consumption

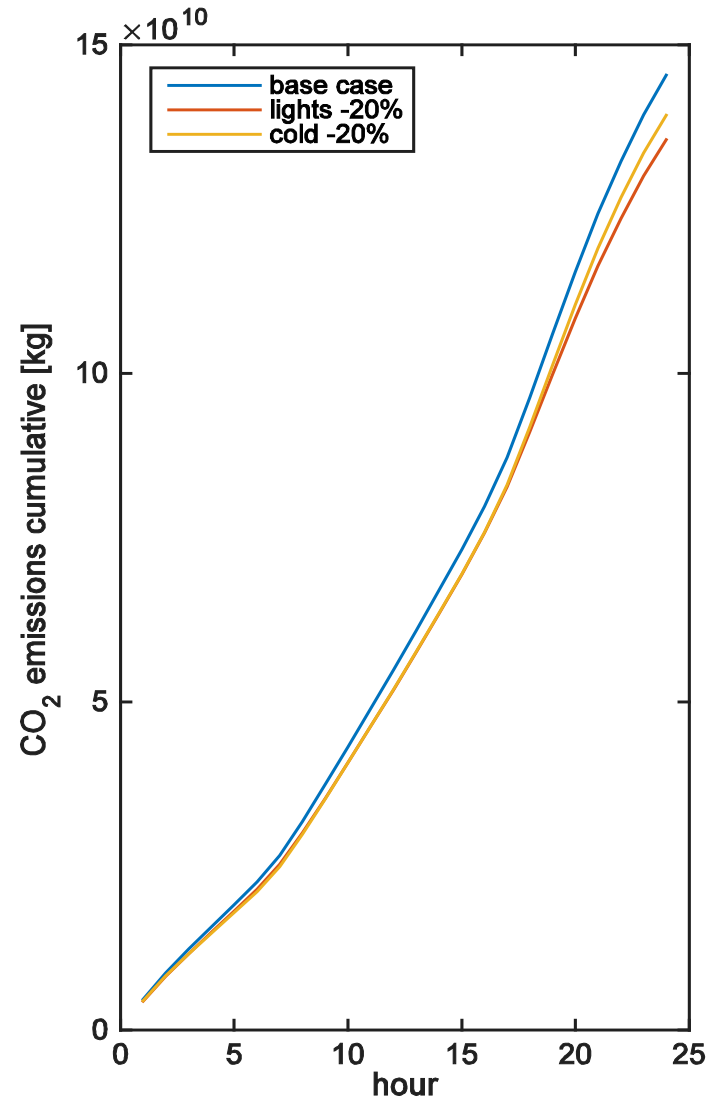
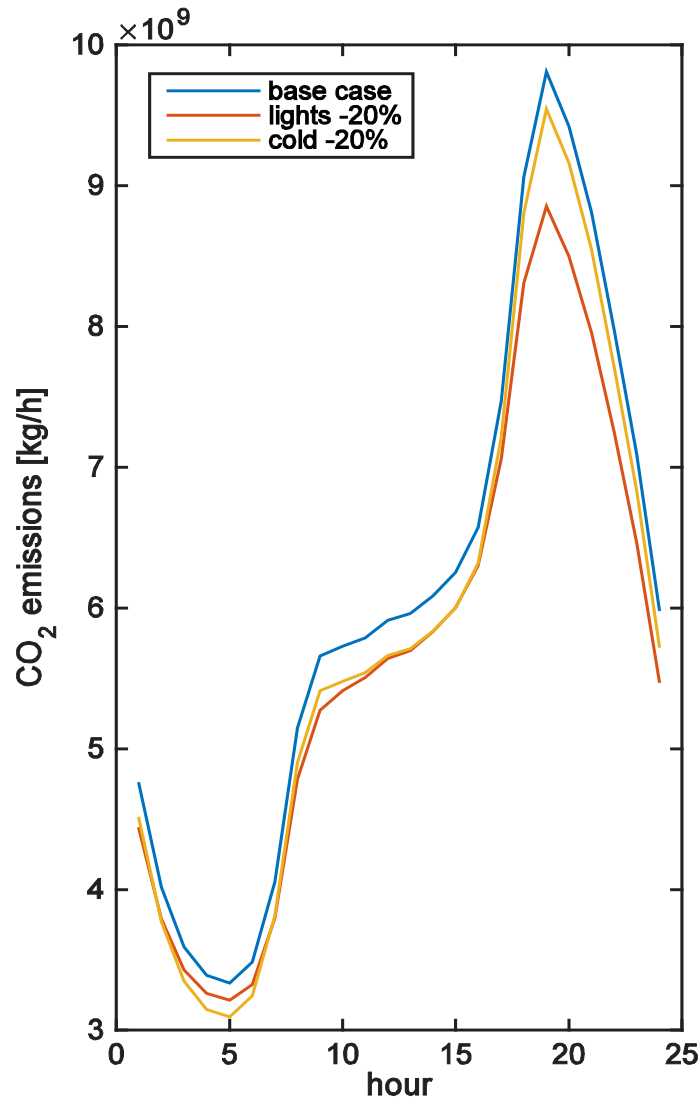
The emission effect of savings:

Emission summer constant per hour



The emission effect of savings

Emission winter constant per hour



Results alternative A

Constant emissions per hour (in each season)

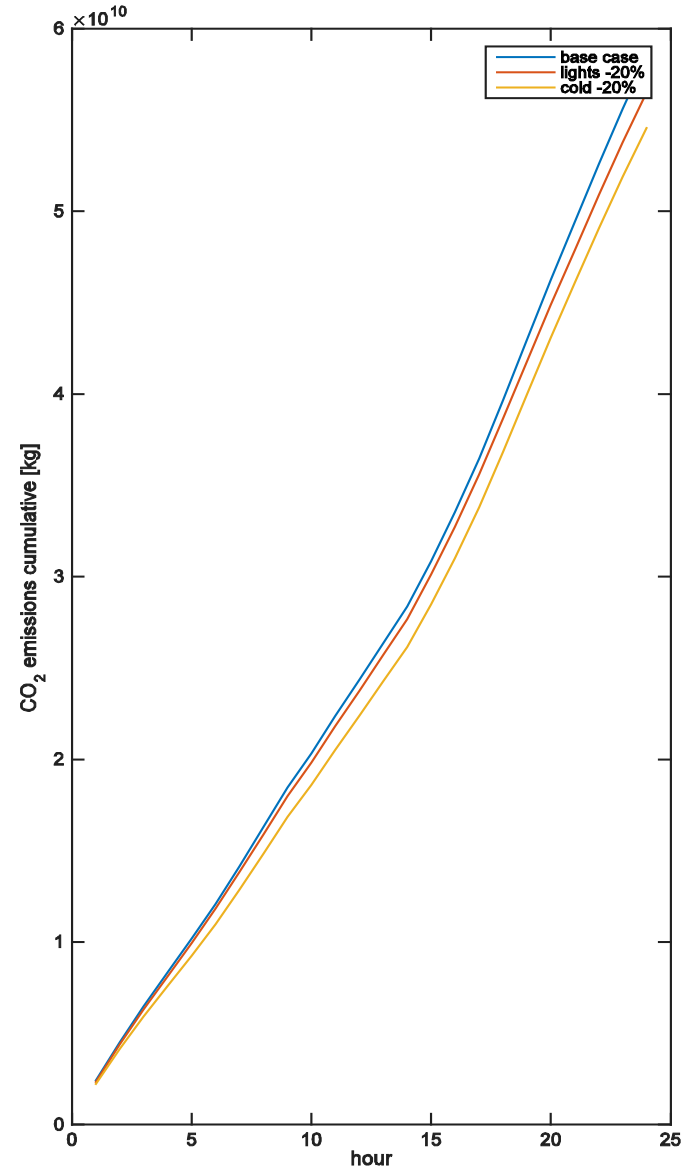
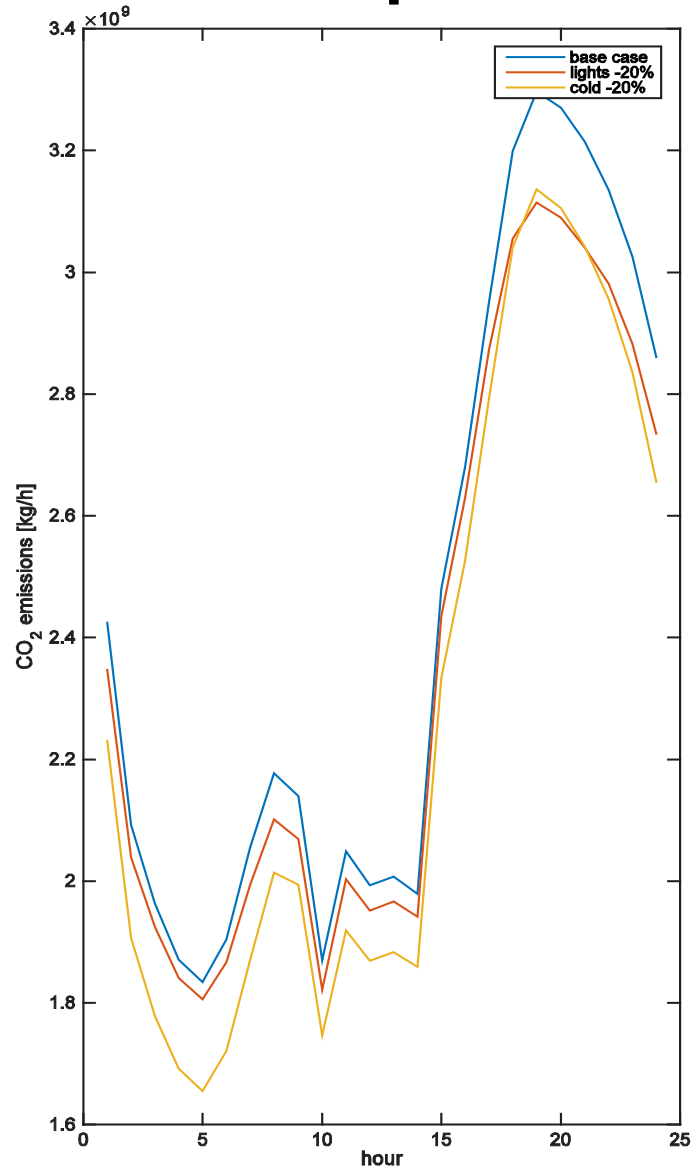


- Emissions are reduced for all hours following the consumption reduction
- Emissions profile follows the profile of the load for the appliance
- Summer effect is an emission reduction of 3.3% for light and 6.6% for cold appliances
- Winter effect is a reduction of 6.7% for light and 4.2% for cold appliances
- Net effect (winter+summer) accumulated is an emission reduction of **5.6% for light** and 5.0% for cold appliances
- An efficiency increase of similar size is thus more attractive for lighting than for cold appliances
- Additionally the winter reduction of consumption and probably peak capacity would make savings in lighting consumption have a higher value as well

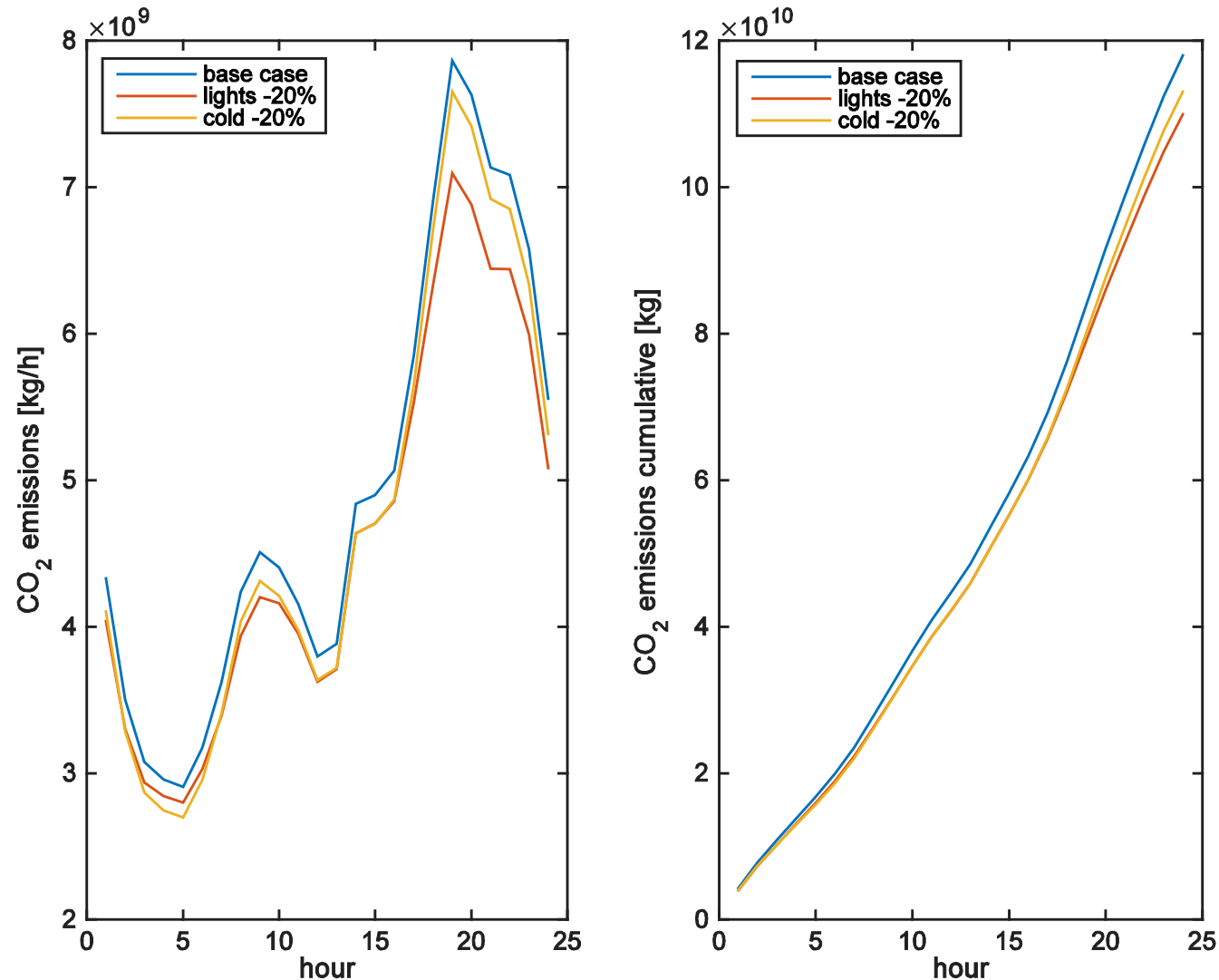
Calculation alternative with varying emissions per hour

- Alternative B
- Emissions vary according to the average emission content per hour for the season examined
- This alternative quantify the effect of varying ***hourly emissions*** within the season

Calculation alternative with varying emissions per hour, summer season



Calculation alternative with varying emissions per hour, winter season



Results alternative B

Varying emissions per hour

- Peak emissions (and level) are reduced compared to constant emissions
- That means the consumption pattern for these appliances have higher weight on the hours with low emissions
- Emissions profile for first half of day quite different (not gradual increase)
- Summer savings effect is a reduction of 3.4% for light and 6.7% for cold appliances
- Winter effect is a reduction of 6.8% for light and 4.0% for cold appliances
- Net effect (winter+summer) accumulated is an emission reduction of **5.7% for light** and 5.0% for cold appliances
- Net effect for both categories is marginally higher than if constant emission are used - thus the average emission at hours with large consumption reduction is a bit more than the constant emissions - **not as big effect as expected**

Preliminary conclusions

- Consumption profiles for household appliance categories vary substantially both during the day and seasonally
- Savings in terms of efficiency for appliance would thus yield considerably different contributions to emissions and capacity requirement in the power system
- Static example calculations show that 20% efficiency increase would give an emission reduction of **5.7% for light** and 5.0% for cold appliances
- This difference is mainly due to the higher share of light savings during the winter and not the daily variation in emissions and the load profiles
- Adding a capacity requirement value to the savings from lighting would shift the preference further towards savings in lighting compared to cold appliances
- Further work will investigate marginal hourly emission effects and the dynamic properties including the capacity value of the savings when optimizing investment in power capacity

Thank you for your attention!

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